Identification of Barriers Affecting the Movement of Morrison Creek Lamprey (*Lampetra richardsoni marifuga)* Within its Natural Range

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IDENTIFICATION OF BARRIERS AFFECTING THE MOVEMENT OF MORRISON CREEK LAMPREY (*Lampetra richardsoni marifuga)* WITHIN ITS NATURAL RANGE

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ABSTRACT

Wade, J., and Beamish, R. 2014. Identification of barriers affecting the movement of Morrison Creek lamprey (*Lampetra richardsoni marifuga)* within its natural range. Can. Manuscr. Rep. Fish. Aquat. Sci. 3043: iv + 16 p.

Morrison Creek lamprey, a distinct and endangered form of the western brook lamprey is recently proposed as a subspecies is found only in one creek on Vancouver Island, British Columbia has decreased in abundance in recent years. Concern over their decline prompted the examination of their habitat for identification of potential barriers to movement. Habitat fragmentation is a concern for this species as they spend their entire life in this one body of water. Three barriers to their movement were examined, two were considered impassable. To ensure that movement is not restricted and survival is not jeopardized, one culvert needs to be modified and a v-notched weir needs to be removed.

RÉSUMÉ

Wade, J., et Beamish, R. 2014. Désignation des obstacles au déplacement de la lamproie du ruisseau Morrison (*Lampetra richardsoni marifuga*) dans son aire de répartition naturelle. Can. Manuscr. Rep. Fish. Aquat. Sci. 3043: iv + 16 p.

La lamproie du ruisseau Morrison, une forme distincte et en voie de disparition de lamproie de l'ouest récemment proposée comme sous-espèce et qui ne vit que dans un ruisseau de l'île de Vancouver (Colombie-Britannique), a connu un déclin de son abondance au cours des dernières années. Les préoccupations concernant ce déclin ont entraîné un examen de l'habitat de l'espèce en vue de désigner les obstacles possibles à son déplacement. La fragmentation de l'habitat est préoccupante pour l'espèce puisque celle-ci passe toute sa vie dans ce cours d'eau. Trois obstacles à son déplacement ont été examinés et deux ont été considérés comme infranchissables. Afin de veiller à ce que le déplacement de la lamproie ne soit pas restreint et à ce que sa survie ne soit pas mise en péril, un ponceau doit être modifié et un déversoir à échancrure triangulaire doit être retiré.

INTRODUCTION

Globally, the negative effects of dams and man-made obstructions on the movements of fish have received considerable attention in recent years due mainly to the construction of hydro-electric dams on major fish bearing rivers (FAO 2001). The negative effects of habitat fragmentation or discontinuity caused by man-made obstructions on anadromous or potamodromous fish species range from disruption of migration to localized extinction (Beamish and Northcote 1989; Baras and Lucas 2001; McLaughlin et al. 2006).

There is, by comparison to commercial species in larger bodies of water, little effort placed to understand the effects of low-head barriers on non-commercial species in small bodies of water. Morrison Creek lamprey, *Lampetra richardsoni marifuga* is one such animal.

The Morrison Creek Lamprey

Morrison Creek lamprey is an example of an extreme endemic; found only in Morrison Creek in Courtenay, British Columbia, on Vancouver Island (National Recovery Team for Morrison Creek Lamprey 2007). Morrison Creek lamprey feeds in the laboratory by parasitizing a variety of fish species, and the adult has been shown to live one year longer than *L. richardsoni* (Beamish 1987). Youson (2004) considered that the Morrison Creek lamprey could represent a step in the evolution of lampreys by identifying five explanations for its existence. One possible explanation was that the Morrison Creek lamprey represented an intermediate stage in the evolution of *L. richardsoni* from *L. ayresii*. What is relevant to this paper is that the Morrison Creek lamprey is valuable scientifically as it is the only known living representative available to study how the non-parasitic life history types have evolved. Understanding how this change occurs is a step in the understanding how lamprey in general have survived for over 300 million years.

Efforts have been made to understand the life history of Morrison Creek lamprey since it was first discovered in the late 1970s and subsequently described in 1987 (Beamish 1987); however, the abundance and general population dynamics of this lamprey remain unknown. Morrison Creek lamprey has been described as *Lampetra richardsoni* variety *marifuga* (Beamish 1987) and is recognized as such in the Species at Risk Act recovery strategy (Species at Risk Act, SC 2002, c 29). It has recently been proposed as a sub-species of the Western Brook lamprey, *L. richardsoni* (Beamish 2013).

It is acknowledged that there is taxonomic uncertainly with respect to this animal and in particular the acceptance in the scientific community of the category "sub-species" in general. However, the aim of this report is to identify and provide information on barriers to the movement of lamprey, how the animal is taxonomically classified is not relevant to the potential impacts due to habitat fragmentation. Therefore, for the remainder of this report, we will refer only to Morrison Creek lamprey and not the Latin trinomial.

In 1995, the Morrison Creek lamprey was assessed as endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and is currently protected under Canada's *Species at Risk Act* (SARA); as such, it is a requirement in legislation that an action plan be

created based on the species' recovery strategy (Species at Risk Act, SC 2002, c 29). As a part of the recovery strategy, a long term monitoring program is to be developed and implemented to assess the abundance and distribution of this species; currently there is no estimate of abundance.

The Study Area

The Morrison Creek watershed has an area of approximately 890 ha (Ellefson 2003) comprised, in part, by the headwaters (543 ha) and a series of streams and channels in addition to the wetlands (90 ha). The headwaters are contained within a large escarpment. Groundwater from this area provides clean cool water year round to the creek. Morrison Creek (approximately 23.7 km in length) extends from the Linton Conservation Area to its confluence with the Puntledge River in Courtenay; it flows through the jurisdictions of the Village of Cumberland, the Regional District of Comox-Strathcona, and the City of Courtenay. The majority of the creek is found within an urban setting of homes, businesses, parks, roads and bridges.

Population Trends and Conservation

Passive live traps were placed in several areas of Morrison Creek from the late 1970s to the late 1980s (Beamish 2013) but no further sampling was undertaken until 2011 and again in 2012. Considerably fewer animals were captured in 2011 and 2012 than in the 1980s, suggesting a major decline in abundance (Beamish 2013). There are many threats to fish population decline. The identification of potential barriers to lamprey movement was undertaken because it was known that there had been some remediation to parts of the stream for salmon habitat restoration, the results of which may not be consistent with lamprey habitat requirements. In order to assess any potential impacts of restricted movement it was necessary to first determine what would constitute an impassable obstruction for lamprey in Morrison Creek and if obstructions were present.

The ability of an animal to pass a barrier varies with biological factors such as: species, life stage, body size, motivation and behaviour, presence of predators; and physical factors such as: temperature and water discharge (Cahoon et al. 2007a). Passability may also vary depending on whether an individual or a population is being considered (Kemp et al. 2010). If the passability of an individual is being considered, it may be the number of attempts required to pass an obstacle that is most important (Kemp et al. 2010). If the context is at the population level, passability can be defined as the number of successful passes as a proportion of the number of fish attempting to pass (Haro et al. 2004).

The identification of potential physical obstructions to lamprey movement was based on vertical height (drop) characteristics such as hydraulic head, water turbulence and gap width of structure as well as slope/swim characteristics such as length, slope and resting locations downstream. These physical attributes may interact with environmental factors such as water flow (high or low) and debris may cause temporary or permanent fragmentation of habitat. Physical barriers in general have proven effective in controlling sea lamprey (*Petromyzon marinus*) in the Great Lakes (Lavis et al. 2003) and low-head barriers of 0.4-2 m in height have proven an effective method of controlling their movement (McLaughlin et al. 2006). It is not unreasonable to assume that barriers of similar height would be impassable to the much smaller Morrison Creek

lamprey.

In this study we examined the physical constructs and determined if these objects were fragmenting an already small habitat.

MATERIALS AND METHODS

Stream survey

In July of 2012 Morrison Creek was surveyed from its convergence with the Puntledge River to the source. Where it was not possible to walk, observations were made from the shore. Areas deemed potentially impassable to lamprey were identified using GPS (Lowrance iFinder Expedition C) and photographs taken. In May of 2013, these potentially impassable areas were re-visited and physical measurements were taken. Culvert slope was measured using a Suunto clinometer, all other obstacle measurements were made with a surveyor's tape measure and meter stick as appropriate.

Passability Criteria

The Scotland and Northern Ireland Forum for Environmental Research commissioned a document (SNIFFER no date) outlining a rapid assessment method to assess obstacles to fish migration. This document defines criteria for determining passability for many species including lamprey. They do not however specify which species of lamprey. These criteria were applied as it is known that there are three lamprey species present in the United Kingdom the smallest of which, adult European brook lamprey being comparable in size to adult Morrison Creek lamprey (100-150 cm) (Beamish 1985). Although this is not an ideal surrogate for Morrison Creek lamprey, it is believed the criteria would be comparable for animals of similar size.

The passability criteria for the upstream movement for adult lamprey is determined based on three assessments: vertical drop/jump, slope/swim and, steps/series of jumps (SNIFFER no date). These criteria were applied to the potential barriers to upstream lamprey movement for vertical drop/jump (Table 1) and slope/swim (Table 2) assessments; no steps or series of jumps were encountered and therefore this assessment was not applied. Passability scores were assigned based on measurements taken for each potential obstruction identified in the stream survey. A passability score of 0 constitutes an impassable, complete obstacle to fish movement; a score of 0.3 is a partial high impact obstacle, or the obstacle is impassable for a proportion of time; a score of 0.6 is a partial low impact obstacle and; a score of 1 constitutes no obstacle. If a 0 score is obtained in any of the criteria evaluated the obstacle is considered impassable.

Table 1. Adult lamprey upstream vertical drop/jump criteria (from SNIFFER, no date)

	Passability Score			
	1	**0.6**	**0.3**	**0**
Hydraulic head: Any structure	≤ 0.15m	0.16-0.25 m	0.26-0.29 m	≥ 0.3 m
Debris dams with porous gap sizes >0.2 m	any height	any height	any height	any height
Resting locations for fish downstream	Present	N/A	Absent	N/A
Lip and/or standing wave present	May be present but does not restrict fish passage	N/A	May be present and may locally restrict fish passage	N/A
Water turbulence associated with structure	Low	N/A	Moderate	High
Debris /sediment blockage	May be present but does not restrict fish passage	Present and may locally restrict fish passage	N/A	N/A
Gap width for notched weirs & culverts	≥ 0.15m	0.10-0.14 m	0.06-0.09 m	≤ 0.05m

Table 2. Adult lamprey upstream slope/swim criteria (from SNIFFER, no date)

	Passability Score			
	1	**0.6**	**0.3**	**0**
Effective length of structure	≤ 3m	4-9m	10-49 m	≥ 50m
Slope of structure				
Length ≤ 3m	≤ 15%	16-25%	26-39%	≥ 40%
Length 4-9m	≤ 10%	11-15%	16-19%	≥ 20%
Length ≥ 10m	≤ 5%	6-10%	11-14%	≥ 15%
Effective resting locations for fish downstream	Present	N/A	Absent	N/A
Lip and/or standing wave present for all structure	May be present but does not restrict fish passage	N/A	May be present and may locally restrict fish passage	N/A
Water turbulence associated with structure	Low	N/A	Moderate	High
Debris /sediment blockage	May be present but does not restrict fish passage	N/A	Present and may locally restrict fish passage	N/A
Gap width for culverts, debris dams and overshot sluices	≥ 0.15m	0.10-0.14 m	0.06 -0.09 m	≤ 0.05m

Mapping

Trapping locations on Morrison Creek from 1983, 1984 and 1987 (Beamish 2013) were mapped in relation to the identified barriers (Figure 1). Similar live downstream collection traps were used in the 1980s as were used in 2011 and 2012, however, their deployment locations were different as some sites used in the 1980s were not suitable for trapping 2011 and 2012. The number of traps deployed varied with up to three traps per season being placed in Morrison Creek in 1983, 1984 and 1987 to capture live lamprey for various experiments. In each of 2011 and 2012, three traps were used (Wade 2011, 2012).

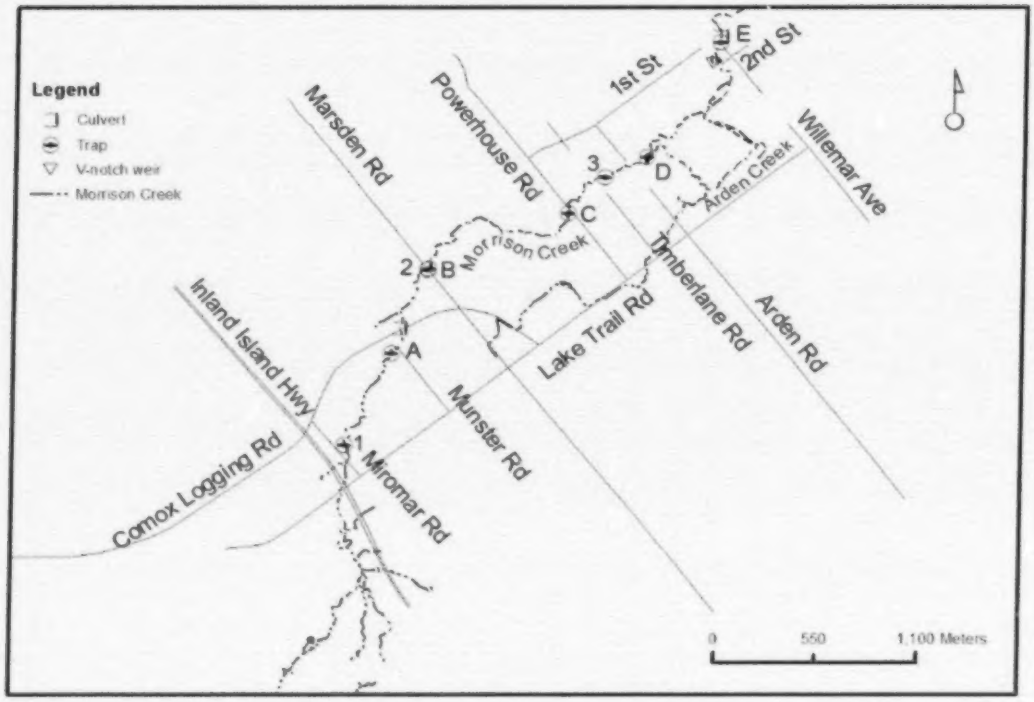

Figure 1. Map of Morrison Creek identifying the locations of Barriers 1-3 in relation to trapping sites in 1983, 1984, 1987 (Sites 1-3) and trapping sites in 2011 and 2012 (Sites A-E) (not all sites were used in all years). Barrier 1 (culvert) is located between trapping sites A and B; barrier 2 (v-notched weir) is located between trapping sites D and E; barrier 3 (culvert) is located immediately downstream of trapping site E.

Traps were installed in up to three locations (Sites 1-3) in 1983, 1984 and 1987 in Morrison Creek (Figure 1). In 2011, two sites were trapped for the duration of the field season, one in Roy Morrison Park (Site D), the other at Willemar and 1st Street (Site E). The Munster Road trap (Site A) was removed approximately half way through the season and re-installed at Powerhouse Road (Site C). In 2012, three traps were monitored, the Roy Morrison Park trap (Site D), Marsden Road trap (Site B) and Willemar and 1st Street trap (Site E). Physical barriers have been identified in relation to trapping locations (Figure 1).

RESULTS

Stream survey

Three barriers to lamprey movement, two culverts and one v-notched weir, were identified in Morrison Creek and passability criteria applied for vertical drop/jump (Table 3) and slope/swim (Table 4).

Table 3. Value and passability scores for upstream migrating lamprey vertical drop/jump criteria as determined in 2013.

	Barrier 1		Barrier 2		Barrier 3	
	Value	**Score**	**Value**	**Score**	**Value**	**Score**
Hydraulic head						
Any structure	33 cm	0	40-55 cm	0	13 cm	1
Debris dams with porous gap sizes >0.2 m	NA	NA	NA	NA	NA	NA
Resting locations for fish downstream	Present	1	Present	1	Present	1
Lip and/or standing wave present	None	NA	None	NA	None	NA
Water turbulence associated with structure	Moderate	0.3	Moderate	0.3	Moderate	0.3
Debris /sediment blockage	None	NA	None	NA	None	NA
Gap width for notched weirs & culverts	170 cm	1	30 cm	1	190 cm	1

Table 4. Value and passability scores for upstream migrating lamprey slope/swim criteria as determined in 2013.

	Barrier 1		Barrier 3	
	Value	**Score**	**Value**	**Score**
Effective length of structure	2862 cm	0.3	1561 cm	0.3
Slope of structure Length ≥ 10m	1%	1	2.5%	1
Resting locations for fish downstream	Present	1	Present	1
Lip and/or standing wave present	None	NA	None	NA
Water turbulence associated with structure	Moderate	0.3	Moderate	0.3
Debris /sediment blockage	None	NA	None	NA
Gap width for culverts	170 cm	1	190 cm	1

Barrier 1: Culvert (49°40'16.35"N; 125° 2'23.51"W)

Barrier 1 is a culvert located under Comox Logging Road, in Courtenay, upstream from the intersection of this road and Marsden Road. The culvert is a standard corrugated metal culvert. The approximate dimensions of the culvert are: 297 cm in diameter, 198 cm in height and 2682 cm long with a corrugation depth of 6.4 cm (Figure 2).

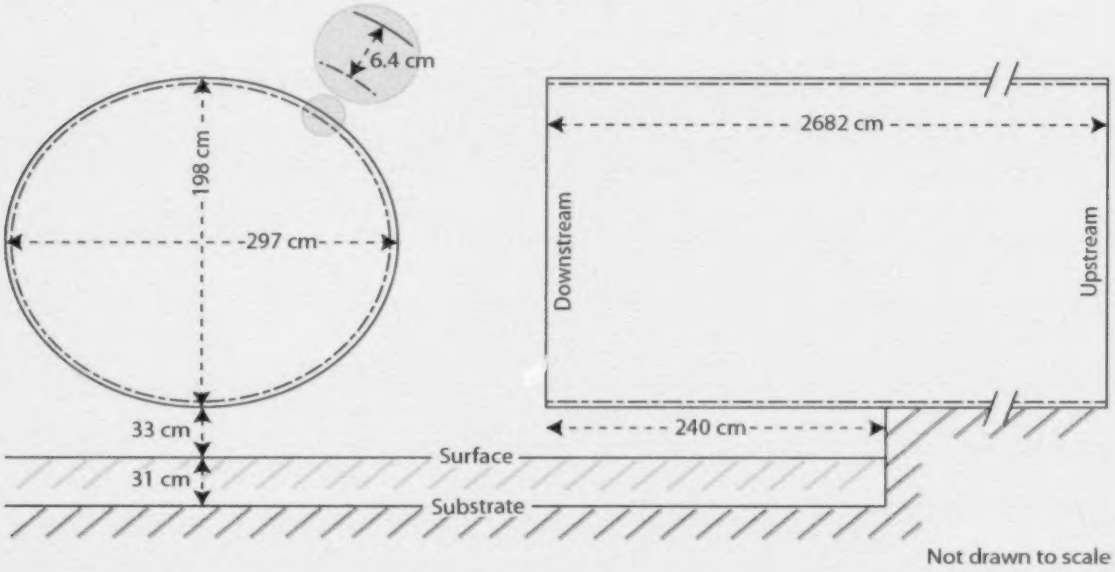

Figure 2. Schematic of Barrier 1, a hung culvert located at 49°40'16.35"N; 125° 2'23.51"W. Measurements taken in May, 2013.

The upstream end of this culvert poses no impediment to the movement of lamprey. There is evidence of beaver activity immediately upstream and it is highly probable that water flow is changed somewhat with these activities, however lamprey have the ability to move under and around obstacles such as sticks, twigs and mud used in the building of beaver dams and lodges. The upstream end of the culvert is level with the substrate and water flow can continue to move into the culvert at all times.

The downstream side is a considerable obstacle to the upstream movement of lamprey. This obstacle is a hung culvert, overhanging the bank by approximately 240 cm. The distance from the bottom mid-point of the culvert to the substrate is 64 cm (as measured on May 2013) the distance of water fall from the mid-point of the culvert to the surface of the water was 33 cm. Water was exiting the culvert with high turbulence making it difficult to measure depth of water (Figures 3a, b).

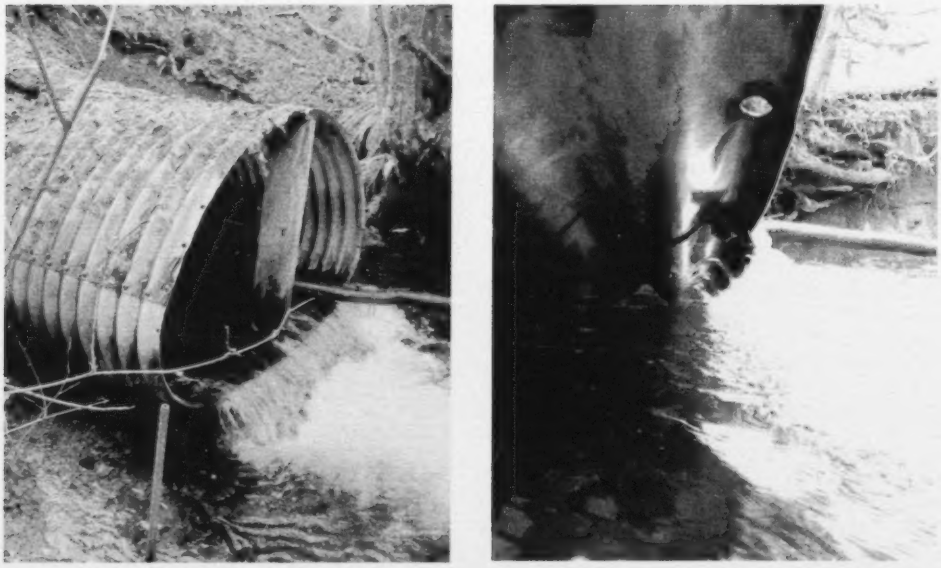

Figure 3. Photographs of Barrier 1, a hung culvert, taken in May, 2013. A) Downstream view of culvert demonstrating the distance from the lip of the culvert to the surface of the water as well as water turbulence B) Close up of culvert overhang and distance from lip of the culvert to the surface of the water.

When applying the vertical drop/jump criteria, the vertical head rates a passability score of 0 making this barrier automatically impassable to lamprey without any further analysis. However, analysis was continued to provide information for recommendations. Moderate water turbulence associated with the culvert rated a passability score of 0.3. The presence of resting locations downstream of the culvert as well as the gap width of the culvert scored 1.

The slope/swim criteria (Table 4) applied to the culvert showed that the slope of the structure given the length posed no impediment to passability of lamprey although the length of the structure by itself was found to be a partial obstacle with a passability score of 0.3. Although the length of the culvert cannot be changed, modifications, such as baffles, may be able to aid in lamprey passage. The gap width of the culvert poses no impediment to movement.

Barrier 2: V-notch weir (49°41'7.62"N; 125° 0'59.29"W)

This V-notch weir is installed at the end of 2nd Street, upstream from the intersection of First Street and Willemar Road in Courtenay. The weir was installed in the 1980s to aid in the passage of anadromous salmon in Morrison Creek. Adjacent to this weir, a diversion channel was rehabilitated in 2009 to allow fish to circumvent the weir. Unfortunately, during low water, the diversion channel may become dry and the only available passage upstream and downstream is through the weir.

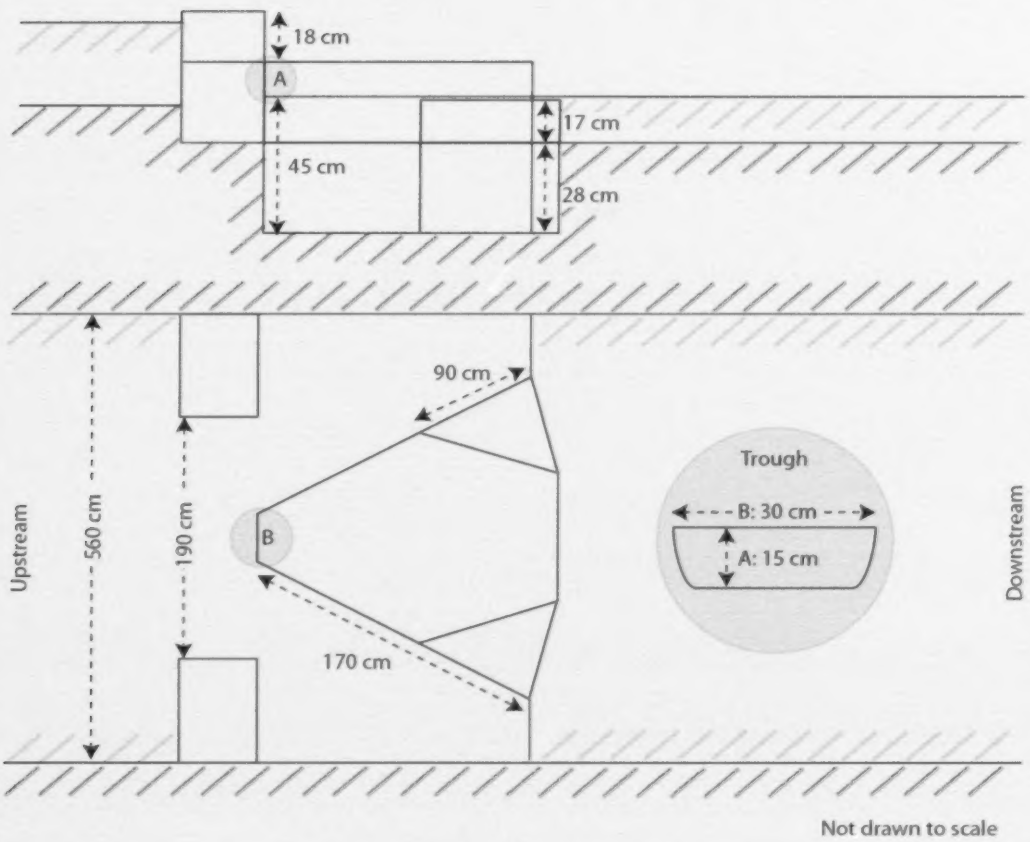

Figure 4. Schematic of Barrier 2, a v-notched weir located at 49°41'7.62"N; 125° 0'59.29"W. Approximate measurements taken May, 2013. Side view above, aerial view below.

The vertical drop as measured in May 2013 (Figure 4) from the bottom of the v-notch to the surface of the plunge pool was between 40-55 cm, the distance from the bottom of the v-notch to the sediment surface was 85cm. As there was high water flow, all of the water was not diverted into the notch but fell over plywood sheeting creating a "waterfall" into the pool below (Figure 5). At the base of the waterfall is a plunge pool which is barricaded off from the rest of the stream by a wall that on the inside is approximately 45 cm deep and on the outside is approximately 17 cm deep. This wall may be of significance to lamprey during times when water flows are decreased. There are no impediments to the downstream migrating juvenile lamprey unless the water levels are low and they become entrained in the plunge pool.

Figure 5. Photograph of Barrier 2, v-notched weir, taken in May, 2013.

There is a retaining wall over which the water falls and a "step" on each side, currently submerged under the water. The depth from the wall to these steps is approximately 43 cm.

When applying the vertical drop/jump criteria, the vertical head rates a passability score of 0 making this weir automatically impassable to lamprey without any further analysis (Table 3). However, the analysis was continued in order to provide information for recommendations. Moderate water turbulence was observed as a result of this weir rating a passability score of 0.3. The presence of resting locations downstream as well as a gap width of 30 cm both rated passability scores of 1 making these features no impediment to lamprey movement.

Because slope/swim criteria only apply to sloping weirs, culverts, fords and bridge footings, rapids, undershot sluices and sloping fishways (SNIFFER no date) this analysis was not performed.

Barrier 3: Culvert (49°41'12.43"N; 125° 0'58.46"W)

This culvert is located under First Street in Courtenay at the intersection of Willemar Road near Puntledge Park. The obstacle is a hung culvert, overhanging the bank by approximately 70 cm. It is a standard corrugated metal culvert approximately 347 cm in width, 220 cm in height and 1561 cm long with a corrugation depth of 6.4 cm (Figure 6).

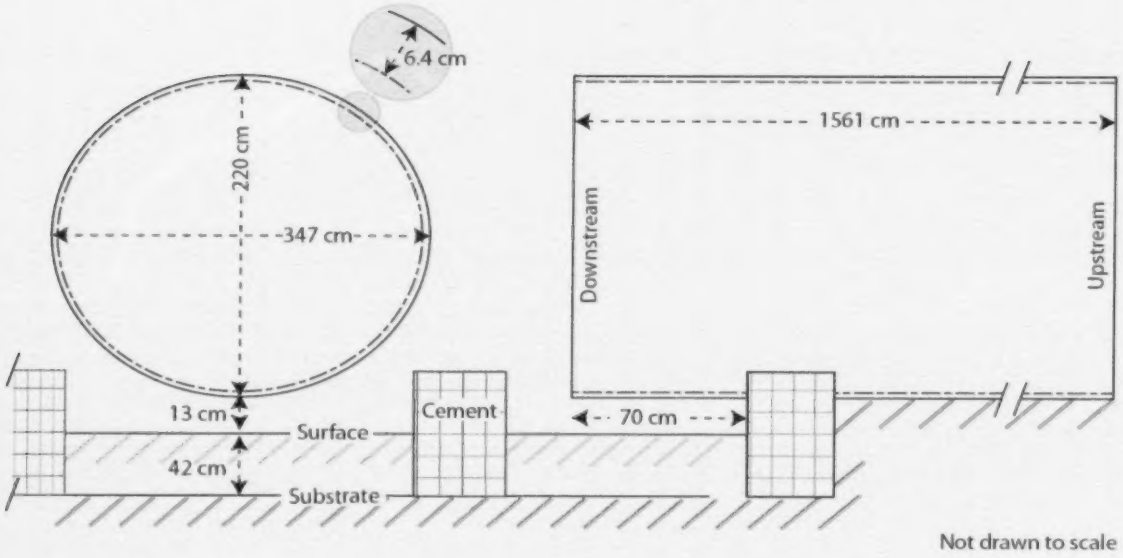

Figure 6. Schematic of Barrier 3, a hung culvert located at 49°41'12.43"N; 125° 0'58.46"W. Measurements taken in May, 2013.

The upstream end of this culvert poses no impediment to the movement of lamprey. The downstream end in May 2013 did not pose an impediment to lamprey movement but at very low water levels, it may be an issue (Figure 7). The distance from the bottom mid-point of the culvert to the substrate is 55 cm, the distance of water fall from the mid-point of the culvert to the surface of the water was 13 cm.

When applying the vertical drop/jump criteria, the vertical head rates a passability score of 1, no obstacle to movement (Table 3). Moderate water turbulence associated with the culvert rated a passability score of 0.3, a partial high impact obstacle. The presence of resting locations downstream of the culvert as well as the gap width of the culvert scored 1, no obstacle, as was found for the other two barriers.

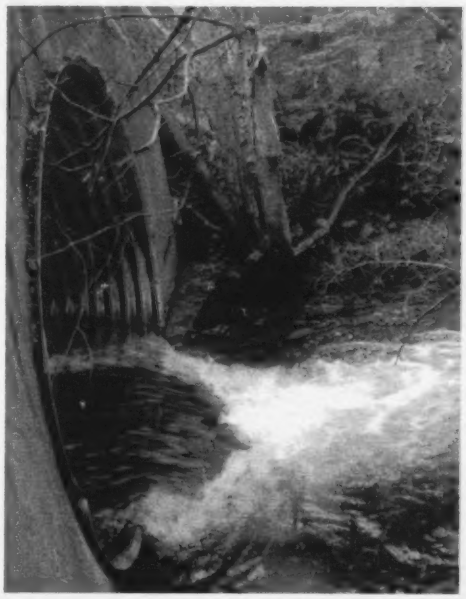

Figure 7. Photograph of Barrier 3, a hung culvert, taken in May, 2013.

The slope/swim criteria (Table 4) applied to the culvert showed that the slope of the structure given the length posed no impediment to passability of lamprey, although the length of the structure by

itself was found to be a partial obstacle with a passability score of 0.3, the same result as found for the other culvert. It is possible that modifications to the culvert may be able to aid in lamprey passage. The gap width of the culvert poses no impediment to movement.

Both barriers 1 and 2 are impassable to lamprey movement, barrier 3 is considered a partial obstruction.

Mapping

Mapping trapping sites in relation to barrier locations (Figure 1) was performed in order to discuss the possibility of impacts on catch rates due to habitat fragmentation caused by barriers.

Barrier 1, the hung culvert under Comox Logging Rd., is located immediately downstream of trapping location 1 (used in the 1980s) and immediately downstream of trapping location A (used in 2011, 2012) (Figure 1). Between barrier 1 and barrier 2, the v-notched weir, are trapping sites 2 and 3 (used in the 1980s) and trapping sites B, C, D (used in 2011 and/or 2012). The third barrier, a hung culvert under 1st St. is located immediately downstream of trapping site E used in 2011 and 2012.

Based on the catch data available it is not possible to attribute reductions in catch with presence of barriers.

DISCUSSION

Although fishways have been used for years to allow safe passage of fish around obstructions such as dams or to aid in passage during low water events, they were created for the benefit of a target species and in British Columbia, most typically, salmonids. Two obstacles have been identified as impassable barriers to the upstream movement of Morrison Creek lamprey, a culvert and a v-notch weir. The Town of Courtenay believes that Comox Logging Road and the corresponding culvert over Morrison Creek have been in place since at least the 1940s, quite possibly longer. They have no records of repairs to the culvert or road, thus it is difficult to answer the question, "has the culvert contributed to the habitat fragmentation and subsequent decline in numbers of lamprey trapped since the 1980s?" This report does not suggest that the impassable objects identified are the sole contributor to the observed decline in catches but their presence has fragmented the habitat of Morrison Creek lamprey.

Review of abundance

Trapping results suggest a decline in the Morrison Creek lamprey over a time span of more than 30 years (Beamish 2013). It was evident that based on similar time frames, June and July, those sites trapped in the 1980s had considerably greater capture success than those sites trapped in 2011 and 2012. For example, catch per day at Site 3 in June and July was 0.93 in 1983, 1.54 in 1984 and 1.05 in 1987 (Beamish 2013). In both 2011 and 2012, Site 3 was found to be no longer suitable for lamprey trapping as the substrate had been changed from one of small rocks and pebbles to that of boulders with a substantial increase in water flow and turbulence. In 2011, a

total of 16 Morrison Creek lamprey were captured in a total of 102 days (Wade 2011). In 2012, this number was reduced to 4 in 143 days (Wade 2012). Compared to 1984 alone, there were 109 Morrison Creek lamprey captured in 183 days (Beamish 2013).

Recommendations

It is recognized that the observed declines in Morrison Creek lamprey abundance may be attributed to many individual and cumulative factors. It is also possible that the observed decline is the result of a natural change to a population. We cannot however disregard the potential effects of movement restrictions to the survival of an endangered species with such a small range. The effects of habitat fragmentation are unknown, the presence of barriers to movement is clear. Until more is understood about the reasons for the decline, we propose that one possible cause, barriers to movements, be eliminated.

Two impassable objects have been identified as barriers to lamprey movement and access to critical habitat within Morrison Creek. At the very least, fixing the obstacles to allow lamprey full access year round will maximize the access to critical habitat. In order to achieve this the downstream side of the culvert located under Comox Logging Road should be remediated in order to eliminate or significantly reduce the hydraulic head. A substrate structure attached to the culvert ending under the water could suffice to address this issue and allow lamprey a surface to "swim up" under low to moderately turbulent water. Ramps have been shown to successfully aid the movement of Pacific lamprey (*Entosphenus tridentatus*) over/through hydroelectric dams on the Columbia River (Reinhardt et al. 2008; Moser et al. 2006), similar structures could be used in Morrison Creek to aid in the passage through culverts. The angle of the structure with respect to water flow should be taken into consideration in the design as well as the development of methods of assessing the success of the structure as has been done for other lamprey species.

In order to address the issues with the v-notched weir, the recommendation is to remove the weir entirely and remediate the stream in accordance with lamprey habitat requirements being cognizant of the requirements of other fish species utilizing Morrison Creek.

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